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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor Degree in Mechatronics Engineering (Hons.)

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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NON-INVASIVE HYPERTENSION MONITORING IN SMART FURNITURE

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Report submitted in partial fulfillment of the requirements
for the award of the degree of
Bachelor of Engineering (HONs) in Mechatronics Engineering

Faculty of Manufacturing Engineering
UNIVERSITI MALAYSIA PAHANG

June 2017

ABSTRAK

Hipertensi adalah pembunuh senyap kerana ia sukar dikesan. Pemeriksaan tekanan darah setiap hari adalah cara yang baik untuk pengesanan awal hipertensi. Komersial mesin untuk memeriksa tekanan darah tinggi biasa mempunyai kapaciti memori tersendiri dan biasanya dilengkapi dengan cuff. Data dalam mesin sukar diambil secara automatik dan pengulangan inflasi tekanan menyebabkan trauma. Kebelakangan ini, penggunaan IoT dengan sistem pemantauan kesihatan rumah menjadi trend. Projek ini mencadangkan pemerikasaan tekanan darah tinggi tanpa cuff, yang terletak di atas kerusi lengan, dengan fungsi menghantar rekod tekanan darah dan kadar nadi secara automatik ke pengkomputeran awan. Sensor optik digunakan untuk mengesan gelombang PPG dari hujung jari pesakit. Tiga parameter yang diambil dari gelombang PPG, termasuk masa upstroke sistolik (ST), masa diastolik (DT), dan masa antara puncak sistolik dan puncak diastolik (P2P) untuk menganggarkan tekanan darah sistolik (SBP), tekanan darah diastolik (DBP), dan kadar nadi (PR). Korelasi dan analisis regresi linear digunakan untuk mengaitkan parameter PPG dengan tekanan darah. Kadar nadi dianggarkan dengan menggunakan masa antara dua puncak optimum berturut-turut dalam gelombang PPG. Perbezaan min anggaran SBP dan DBP membandingkan untuk rujukan masing-masing adalah 3.5909 ± 0.5478 mmHg dan 3.6769 ± 0.6095 mmHg. Perbezaan min anggaran PR berbanding dengan rujukan adalah 5.914 ± 0.6970 BPM. Output, SBP, DBP, dan PR, dimuat naik ke penyimpanan awan, Azure Blob Storage, dan dibentangkan dalam Power BI. Dengan memberikan tekanan darah dan pengukuran kadar nadi dan memuat naik nilai serta-merta ke awan penyimpanan, masalah mesin tekanan darah tinggi biasa telah diselesaikan.

ABSTRACT

Hypertension is a silent killer as it is difficult to be detected. Daily monitoring blood pressure is a good way for early diagnose hypertension. The common commercial hypertension monitoring device only consists of local data storage and normally equipped with cuff. The data from the device is difficult to be retrieved automatically and the repetition of pressure inflation during measurement may cause trauma. Recently, application of Internet of Things (IoT) with home health monitoring system becomes a trend. This project proposed a cuffless hypertension monitoring, which embedded in the armchair, with a feature of automatically upload the recorded blood pressure and pulse rate readings to a cloud storage. An optical sensor is used to detect the photoplethysmography (PPG) wave from the fingertip of the patient. The raw PPG wave is filtered and amplified. Three parameters are taken from the PPG wave, including, systolic upstroke time (ST), diastolic time (DT), and time taken between systolic peak and diastolic peak (P2P) to estimate systolic blood pressure (SBP), diastolic blood pressure (DBP), and pulse rate (PR). Correlation and linear regression analysis are used to correlate this PPG parameter with blood pressure. The pulse rate is estimated by using the time taken between two successive optimum peaks in PPG wave. The mean difference of estimated SBP and DBP comparing to reference is 3.5909 ± 0.5478 mmHg and 3.6769 ± 0.6095 mmHg respectively. The mean difference of estimated PR comparing to reference is 5.914 ± 0.6970 BPM. The output, SBP, DBP, and PR, is uploaded to a cloud storage, Azure Blob Storage, and presented in Power BI dashboard. By providing cuffless blood pressure and pulse rate measurement and instantaneous upload BP and PR readings to cloud storage, the proposed solution has overcome the problem of common hypertension monitoring device.

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LIST OF SYMBOLS

f	Cut off frequency
R	resistance
C	capacitance
r	Correlation Coefficient
x	Explanatory variable
y	Dependent variable
m	Slope
c	Intercept
n	Number of samples
$t_{peak\text{-}to\text{-}peak}$	Time taken between successive optimum peak
$\bar{x}_D$	Mean difference
s_D	Standard deviation
t	Critical value
α	Significance level

LIST OF ABBREVIATIONS

IoT	Internet of Things
PaaS	Platform as a Service
SaaS	Software as a Service
IaaS	Infrastructure as a Service
BP	Blood pressure
SBP	Systolic blood pressure
DBP	Diastolic blood pressure
PR	Pulse rate
BPM	Beats per minute
PTT	Pulse transit time
ECG	Electrocardiogram
NHA	Normalised harmonic area
TAG	Tonoarteriography
PPG	Photoplethysmography
PWV	Pulse wave velocity
FFT	Fast Fourier Transform
TPPG	Transmittance photoplethysmography
RPPG	Reflectance photoplethysmography
csv	Comma separated value
ST	Systolic upstroke time
DT	Diastolic time
P2P	Time between systolic peak and diastolic peak

CHAPTER 1

INTRODUCTION

1.1 Introduction

The purpose of this chapter is to provide general information regarding the project title, Non-invasive Hypertension Monitoring System in Smart Furniture. The background study on hypertension, a method of measuring blood pressure, a method of measuring pulse rate, and Internet of Things (IoT) based home-health hypertension monitoring system are described in the following section. The problem statement, objectives and project scopes are defined in this chapter as well.

1.2 Background Study

Hypertension is one of the chronic cardiovascular disease suffered by over one billion people in the world. Hypertension is defined as abnormal elevation of systolic blood pressure or diastolic blood pressure.

Table 1.1 Classification of adolescent above 18 years old.

Blood Pressure Classification	**Blood Pressure (mm Hg)**	
	Systolic	Diastolic
Normal	< 120	and < 80
Prehypertension	120-139	or 80-89
Stage 1 hypertension	140-159	or 90-99
Stage 2 hypertension	≥ 160	or ≥ 100

Source: (BC Guidelines & Protocols Advisory Committee, 2016) (Tomky, 2004)

Table 1.1 shows the classification of hypertension for adolescents above 18 years old. The normal blood pressure of an adult is below 120 mmHg and 90 mmHg for systolic blood pressure and diastolic blood pressure respectively. When systolic blood pressure (SBP) is over 140 mmHg or diastolic blood pressure (DBP) is over 90 mmHg, it is considered as hypertension. The blood pressure can be classified into four groups, which are normal, prehypertension, stage 1 hypertension and stage 2 hypertension. Prehypertension is when SBP is between 120 and 139 mmHg or DBP is between 80 and 89 mmHg. When SBP between 140 and 159 mmHg or DBP between 90 and 99 mmHg, it is considered as the first stage of hypertension while the second stage is SBP higher than 159 mmHg or the DBP is higher than 99 mmHg (Tomky, 2004). Hypertension is also referred as a silent killer since the disease comes with no symptoms and signs. Hence, daily monitoring of blood pressure becomes a favorable way to prevent hypertension (Gao, Song, Tanaka, & Yamakoshi, 2009).

From the definition of hypertension, the blood pressure (BP) is highlighted as the main parameter to detect hypertension. Blood pressure is the pressure against the wall of arteries as the blood is circulating in arteries. The pressure acts as driving force to push the blood flow from the vessel and to the entire body. It can be divided into two sections, which are, systolic blood pressure and diastolic blood pressure. Systolic pressure is the pressure in the arteries when the blood is pump from the heart, whereas diastolic blood pressure is the pressure in the arteries when the heart is resting (Alton, 2005).

Besides of BP, pulse rate (PR) is also a parameter to diagnose hypertension. The range of pulse rate for an adolescent is between 60 and 100 beats per minute (BPM). The pulse rate depends on the fitness of the body. A person who is slimmer has lower pulse rate. If a person has pulse rate that the higher than the range, he/she is considered tachycardia. On the other hand, it is considered as bradycardia (Fontaine, 2010).

Recently, home health monitoring system, especially for elderly, has become the main focus of researchers. There are many health monitoring system and devices, embedded with bio-sensors, introduced in the market. Most of the parameters such as blood pressure, pulse rate, and body temperature, are usually recorded from the system in order to monitor the vital symptom for the chronic disease. This recorded data is very useful towards long-term health monitoring and prevention if the measurement from the system is reliable.

The home health monitoring system usually embedded in furniture, such as a bed, and chairs which have direct body contact to the user. A prototype of health monitoring room is introduced by Kanazawa University, Japan in 2007. Instead of attaching the sensor on subject's body, all the sensors in this project are embedded in the furniture, including, pillow, bathtub, floor and toilet bowl.

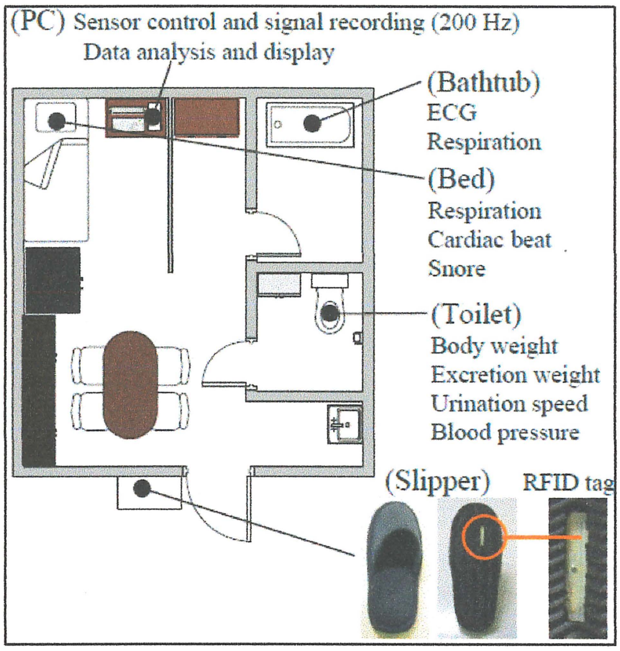

Figure 1.1 Floor map of health monitoring room
Source: (Motoi et al., 2007)

The position of sensors is labeled in the floor map of the room as shown in Figure 1.1. Two parameters are focused by this project which is early diagnosis and treatment of sleep apnea syndrome (SAS) and detects drowning during the bath. The system monitors blood pressure by using reflective optic sensor and pressure sensor, body weight by using weight scale, and respiration for detecting the sleep apnea syndrome by using sensor under the pillow, and ECG in the bath tub to detect drowning. Besides, the slippers of subject's embedded with RFID tag for personal verification purpose (Motoi et al., 2007).

The second example of furniture with the function of health monitoring feature is introduced by Herman Miller, a healthcare furniture company, 2015. The company introduced a sensor-based health monitoring embedded in the chair as shown in Figure

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